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ON THE EFFECTIVITY INCREASE OF TELEMETRY

per Avtomatika i Telemekhanika
Vol XX No. 10, 1959

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Translated by Joseph L. Zygielbaum

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Abstract

Methods are presented for increasing the effectivity of transmission of information with telemetry on the basis of calculation of such spectral characteristics of the measured parameter as the dependence of amplitude oscillations and the errors in measurements on the frequency of oscillations.

A method for transmission with automatic adjustment of the coding system is proposed. The increase in transmission speed and possible reduction of frequency bands are evaluated.

An increase in the effectivity of transmission makes possible the reduction n the frequency band or decrease in transmission time and is achieved on the basis of calculation of the properties of communication during the construction of coding systems. In the information theory by Shennon a general definition is given which encompasses the statistical aspects of information transmission. The effectiveness of transmission is defined as a relation of "actual transmission speed to the capacity of a channel" (Ref 1). In order to evaluate practical systems for transmission, it is expedient to utilize the concept of relative effectiveness of η, understanding that the relation of maximum speed in the creation of information data by the source R_i to the maximum speed of transmission is analogous to the statistical and spectral properties of information by means of the applied coding system R_K, $\eta = R_i/R_K$. At times the increase of effectiveness is conveniently evaluated in the form gain (θ) according to the transmission speed (R): $\theta_R\% = (1 - R_K/R_{KO})\ 100$ or $\theta_R = R_{KO}/R_K$, where R_{KO} and R_K are the original and repeated value of transmission speed of information with the coding system. However, information evaluations (for instance, the speed of transmissions) are usually averaged by separate communications and by time so that comparison with the help of a number of systems of transmission (particularly telemetry) is not always significant. Specifics of telemetry consist of the fact that delays connected with the optimum coding are usually not tolerated and, consequently, it is impossible to increase the average speed of transmission which is based on this method.[a] Therefore, the increase of sensitivity is often evaluated indirectly in the

[a]To the best of the author's knowledge this property of telemetry communication was first formulated by V. A. Ilin.

physical indicators of this system of transmission as a gain on the frequency band during the transition from the primary band W_0 to the again achieved W; that is

$$\theta_W\% = \left(1 - \frac{W}{W_0}\right)100\% \text{ or } \theta_W = \frac{W_0}{W} \tag{1}$$

I. Spectral Characteristics of the Telemetry Parameter

It is possible in a number of cases to increase the relative effectiveness of information transmission on the basis of calculation of the spectral characteristics of these messages during the design of coding systems.[a]

The dependences of the amplitude A(f) of oscillation, the permissible absolute error $\Delta(f)$ in measurements, and the necessary number of graduations $N(f) = A(f)/\Delta(f)$ for transmission of the telemetered parameter from the frequency (f) of its oscillation are investigated in the capacity of spectral characteristics in the given case. These characteristics might be determined from an analysis not only of the source of communication but also of the receiver. Actually the properties of the receiver which make the transmission of some elements of communication unnecessary should be taken into account during the definition of characteristics of the message which is transmitted. Thus, the spectral characteristics might be directed to the input of the coding system.

[a]The expression "coding system" is understood here in a broad sense; that is, as a comparator (coder, modulator, of one form of a signal which carries information to another more convenient for transmission over a communication channel).

The most difficult spectral characteristics, conventionally divided into four types, are shown in Figure 1. Note that the second type of characteristic corresponds to the decrease of amplitude of oscillation; the third type corresponds to the increase of the tolerable error during the increase of the speed of measurement (oscillation frequencies) of the telemetered parameter. The fourth case is a combination of the second and third.

Normally, the telemetry constructions are calculated in accordance with the characteristics of the first type. However, if an actual characteristic of a telemetered parameter differs from the characteristic of the first type, it is not expedient to consider the structure under a maximum frequency of signal change and a maximum number of graduations in a number of cases.

One of the methods for the coordination of the channels of communication (or coding systems) with the spectral characteristics of the signal consists of the separation of the frequency band (which is taken up by the signal), intersectors (with characteristics which are close to proportion), and the linking of the construction of several coding systems which would correspond to these sectors (Refs 2 and 3).

For telemetry, another method of coordinating the communication channels with the characteristics of the signal is proposed, which consists of the construction of an automatic readjustment coding system that would automatically change the number of transmitted graduations as a result of the change in the high-speed

independence from the speed of parameter change.[a] Automatic readjustment is actually a change of the component in the volume of the V signal, although in a number of cases (during a code impulse modulation), the volume V = 2fTN itself undergoes a change.

II. Increase of Effectiveness in the Characteristics of the Second Type

We will examine the interval between the impulse transmissions, which correspond to the changes of the parameter with the frequency f, (Fig 2). The value of the parameter x_i and x_{i+1}, which is at times removed by 1/2f, might differ only within the limits of the zone $\pm A(f)$. The actual increase of information in each ordinate might reach the volume $\Delta I = \log A(f)/\Delta_0 = \log N(f)$. Since the number of graduations which distinguish one message from the other do not exceed $N(f) < N_0$ (Fig 1, II), then it is expedient to transmit in each message that number of N(f) graduations within the limits of which is located the possible change of parameter on the given frequency. However, in telemetry the transmission of incremental changes only is, as a rule, not tolerated, since the correction of readings for the purpose of eliminating possible accumulation of errors is necessary. This leads to the structure of an instrument by which the transmission of parameter changes is connected with the rarer transmissions of absolute value.

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[a]The characters of such transmission have a similarity to certain biological processes; for instance, to the separate reactions of a man. Such a possibility was pointed out by A.A. Kharkevitch (Ref 4). The definition of the signal range introduced here differs somewhat from the data by A. A. Kharkevitch, which is closer to the established definition of transmission speed.

The structural scheme of the device, in which the coordination of the source with the channel is accomplished with the help of several (for instance, two) coding systems, might be as follows: The slow acting structure with a code impulse modulation (KIM) transmits the accurate value of the parameter with a large phase. Over a separate channel are transmitted rapid changes by the method of Δ-modulation or by a variety of this method whereby, with the absence of a parameter change, no transmission of any signals takes place. Figure 3 is a block diagram of the structure which carries out both of these functions. Without going into detail, we will mention that the reverse counter is very convenient in such a coding structure and simplifies the separation of diversion impulses which might differ in value from a unit. The principal necessity for three channels for the transmission of one telemetry message [illegible] ases the expediency of such a method.

More prospective for telemetry is the method of constructing an automatic readjustment of the coding system with the transmission of deviations and absolute values of the parameter over one frequency channel. From all possible variants, we will mention the following coding transmission. During rapid changes of the parameter, dual-impulse code messages transmit one of two combinations which were given the values of +1 or -1 in the system Δ-modulation.[a] During the transmission of a constant component, when the parameter changes slowly, each such

[a]The value of these Δ-messages might also differ from a unit, which corresponds with the characteristics of the fourth type. In addition, an elementary message might consist of not only two, but many impulses (Sec III). With the help of such a method, a multichannel transmission with an occasional separation is possible to accomplish. The specifics are contained in the necessity of successive transmission of first all primary code elements of all channels, and then the secondary, etc.

double-impulse message transmits one of two of the other combinations which correspond to one or zero of the binary code.

III. Increase of Effectiveness with the Characteristics of The Third Type

The characteristics of the third type correspond to the case when the permissible error in telemetry grows with the increase of frequency of oscillation (that is, the speed of measurement) of the parameter and the same maximum values of these oscillations; that is, $A(f)_{max} = A_0$. In a telemetry installation which transmits such information, it is expedient also to apply an automatic readjustment of the coding system.

During a relatively stable operation of the energy system, the dispatcher might register accurate telemetry data, process this data, and execute certain activities with this data. However, in the case of any sharp changes in the controlling parameters, which might be caused by accidents, the dispatcher is not capable of evaluating the events which take place with original accuracy, and the transmission of telemetry data might become much rougher. At the same time, it is important for the dispatcher to obtain these data with minimum delay.

An automatically readjusting telemetry installation might be accomplished with any modulation. A telemetry structure with a width, time division, and coding impulse modulation (WIN, TIN, KIM) can most simply be realized.

In the case of a KIM, there might be available several methods for the accomplishment of a discrete automatic adjustment. One of these methods consists of the processing of the coder, which transmits, by a slow change in the parameter, code messages consisting of n_1 divisions of binary code and, in the case of a rapid change,

shorter messages consisting of $n_2 < n_1$ code divisions. A significant symptom of transition toward rapid but rough transmission might be, for instance, the absence of a synchronizing impulse. The receiving installation should contain a readjusting decoder which distinguishes short and long messages and decodes them. Another possible variation is analogous to the one which was described in Section II with the exception that, in the case of rapid parameter changes, the message of n_2 impulses does not transmit the parameter deviation but the entire scale with an errata of $1/2^{n_2} - 2$. Thereby, two combinations in this message will be used for the transmission of 1 or 0 in the binary code with n_1 divisions ($n_1 > n_2$), which is transmitted during slow changes of the parameter.

With a WIN or TIN, a proportional automatic adjustment is accomplished. Figure 4a is an example of a change of the duration of a measured cycle (message) T in the case of a WIN for two speeds of parameter changes (τ is the measurable time interval).

A structural schematic of an automatic readjustment of a transmitter with WIN (or TIN) is introduced in Figure 4b. The intensity of the indicator is proportional to the measured parameter and becomes equal with the intensity of the sawtooth-like form from Generator 2. Null-circuit 1, which reacts to the variation in these intensities, produces impulses with durations proportional to the intensity of the pickup. During parameter changes, the differential Block 3 emits an intensity (proportional first derivative of the parameter) which increases the frequency of the

generator.[a] In order not to distort the measured cycle, a change in the frequency of the saw-tooth-like intensity is done at the moment of termination of the cycle.

In order to avoid a possible delay in the telemetry transmission, a signal of sufficient magnitude of the second derivative of the parameter could be provided so as to interrupt the started cycle, after which a new cycle will begin at a new speed, with accumulation of saw-tooth-like intensities. Information about the fault of an unfinished cycle might be transmitted, for instance, most simply by a code message.

In order to accomplish these functions, the schematic is provided with a relay element, four control circuits of which are conventionally characterized by contacts. The relay element is operated by a differentiating block (second derivative) and a generator (at a moment of termination of the cycle). The stability of slope of the saw-tooth during the process of the measurable cycles is secured by a memory device in the form of a condenser.

The receiving device (Fig 4c) contains two demodulators (1 and 2) for the purpose of sectional demodulation of the time interval (which is proportional to the parameter τ) and the current time value of the cycle T. In order to obtain readings, it is necessary to divide these values with the help of a special Divider 3; for instance, a logmeter.

During an increase in the frequency of the impulse messages, the decrease in the accuracy of telemetry in the code variation of the telemetry installation takes place because of the decrease in the transmitted sections of the binary code; in

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[a]The differentiating block produces a modulus of the derivative; that is, the signal at its output does not depend on the indication of a parameter change.

the variation of the width-impulse installation this takes place because of the decrease of the absolute value of time deviation.

In order to evaluate the gain by the effectiveness of such a system, assume that a telemetry installation with a WIN transmits a parameter, the characteristic of which is given in Figure 1, III.

First of all, note that the nonadjustable coding device, which is calculated for higher frequency f_B and the number of graduations N_0, should transmit

$$R_{KO} = 2f_B \log_2 N_0 \frac{\text{dual units}}{\text{sec}} \text{ or } V = 2f_B N_0 \frac{\text{grad}}{\text{sec}} \tag{2}$$

We have introduced in our example a case of a linearly interrupted dependence $\Delta(f)$, which corresponds to the structure of WIN with an automatic adjustment, in which the frequency of following the impulse messages is maintained proportionally to the frequency of parameter fluctuations, beginning from a certain value of this frequency f_1. The number of dual units per sec will therefore depend on the frequency $R_K(f) = 2f \log N(f)$, and the number of graduations which are transmitted per sec does not change; that is, $V(f) = V_0$.

In that somewhat idealized case, the speed of generation of information by a source equals the speed of transmission of its coding system $\eta = 1$. The gain in transmission speed $\theta_R = R_{KO}/\max R_K = \log N_0/\log N(f_B)$, since the value R(f) is not constant within the range of $0 < f < f_B$ and $\max R_K(f) = R_K(f_B) = 2f_B \log N(f_B)$.

The gain is determined by the band frequency. If, in the case of a nonadjustable structure, the frequency band in the communication channel is proportional to

f_B, then in our case this band is proportional to the frequency f_1 by an easily accomplishable condition of unchangeable steepness of fronts during the process of automatic adjustment. The frequency gain might be considerable: $\theta_W = W_0/W = f_B/f_1$.

IV. Conclusion

The expediency of special measures directed toward the increasing of the effectiveness of telemetry is, of course, determined by a number of factors and, first of all, by the simplicity of technical feasibility. Side by side with such known methods for more complete utilization of communication channels as the perfection of the quality of elements and nodes, which are used in the channels of the apparatus (stability of filters, generators, etc.), the increase of effectiveness of telemetry on the basis of computing the spectral characteristics of the measured parameter additionally permits the narrowing by several times of the frequency band or the increase of the speed of transmission.

It is expedient, by means of telemetry, to comply the information sources with a communication channel with the help of automatic readjustment of the coding system. This coding system performs a change in the number of transmitted graduations and the speed of telemetry in dependence on the speed of the parameter change.

It is necessary to point out that even if the basic types (second and third) of the examined spectral characteristics contain decreasing dependences of the number of graduations from frequency, that is N(f), nevertheless, the smaller variation in the characteristic A(f) and also $\Delta(f)$ determines the specifics of the transmission system of parameters of each type.

It has been impossible to judge finally, as yet, the typicality of any spectral parameter characteristics. However, it seems most probable that, in the case of industrial telemetry, parameters having the characteristics of the fourth type will be more popular when, with the increase of frequency, it is possible not only to increase the measurement of errors but also to decrease the amplitude of parameter fluctuations.

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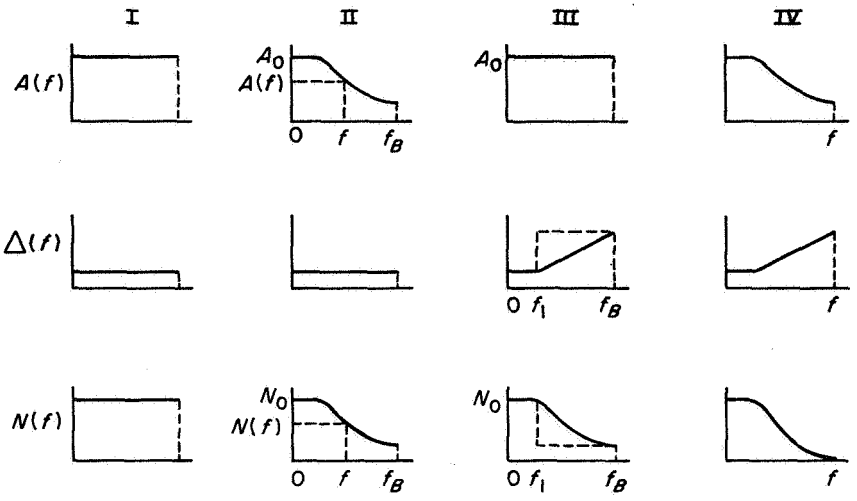
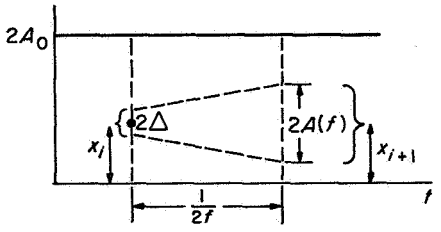


Figure 1. Spectral characteristics of certain parameters which are subjected to telemetry



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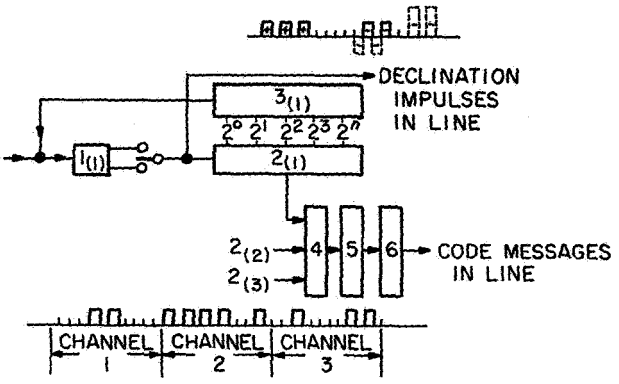

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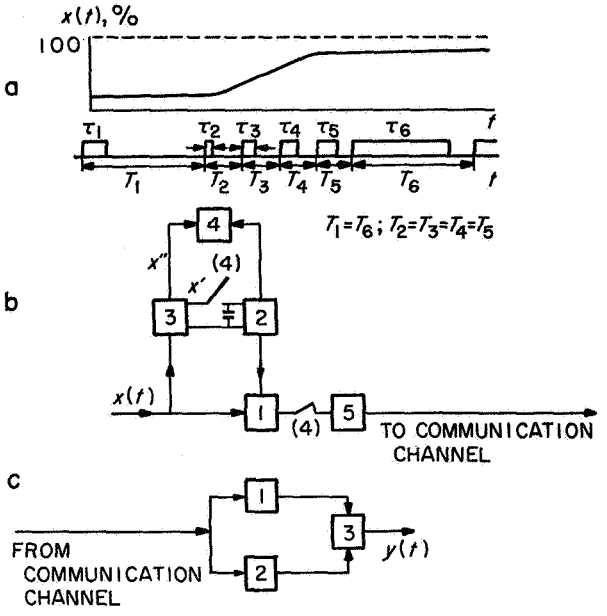

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